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DO ALTERNATIVE GAS ATMOSPHERES FOR PIG STUNNING AFFECT PORK QUALITY?

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I. INTRODUCTION

The use of high-concentration carbon dioxide (CO_2) stunning of pigs prior to slaughter reduces animal welfare before the loss of consciousness [1]. Inert gases such as argon (Ar) and nitrogen (N_2) are described as promising alternatives to CO_2 stunning, as aversive reactions are observed less frequently [2]. One of the reasons why these gases are not yet used in commercial slaughterhouses is the reported reduction of meat quality [3, 4]. In the project "Testing Inert Gases in order to Establish Replacements for high concentration carbon dioxide (CO_2) stunning for pigs at the time of slaughter" (TIGER), we were investigating the effect of different inert gas atmospheres on meat quality in a balanced study design.

II. MATERIALS AND METHODS

This study was carried out on eleven different slaughter days at a conventional slaughterhouse using a dip-lift stunner. On each slaughter day, the pit was filled with Ar, a N_2-Ar mixture (not exceeding 40% Ar) or 90% CO_2, by changing the order within and between the slaughter days to create a balanced study design. With the new and patented gassing technology by Air Liquide Germany GmbH (Krefeld, Germany), a residual oxygen concentration of below 1 % was achieved when the pigs were stunned with the inert gas mixtures. In total, 738 female and castrated male crossbreed fattening pigs (slaughter weight: M = 98.7, SD = 8.3 kg) from six different farms were almost equally distributed to the used gas mixtures. At 45 min *post mortem* (p.m.), pH and temperature (T_{45}) were measured in all animals in the *M. longissimus thoracis et lumborum* (LTL) between the 13th and 14th rib of the left carcass side, and in the *M. semimembranosus* (SM) before chilling. After 24 h p.m., pH and temperature (T_U) were recorded again. Electrical conductivity (EC_U) was also accessed in both muscles from 237 pigs. Additionally, hams from 378 pigs were screened for hemorrhages. To determine the color and the drip loss, 2.5 cm thick slices were taken from the SM of 187 animals. The color before and after storage was determined with the Minolta Chroma Meter using the CIE *L*a*b** system at 6 measuring points per slice of ham. Before packaging in a modified atmosphere with 80 % O_2 / 20 % CO_2, the slices were weighed, stored at 4°C for 72 h and weighed again to determine storage loss. After storage, the pieces were cooked in a water bath at 78°C for 20 - 30 min until a core temperature of 72°C was reached, to determine cooking loss. After another overnight storage at 4°C, the shear force was analyzed using the MORS method, as described in Altmann et al. [5]. The threshold for pale, soft and exudative meat was set at $pH_{45} < 5.8$. For the statistical analysis in R, version 4.2.3., the linear mixed model was used: $y_{ijklmno} = MG_i + D_j + F_k + Gen_l + S_m + W_n + O2_o + \varepsilon$ with the fixed effects MG = main gas, F = farm, Gen = genetics, S = sex, the random effect D = day of investigation and the covariates W = weight, O2 = residual O_2 concentration as well as the residual error = ε. Calculation of Least Square Means (LSM), including the pairwise comparisons of the different groups were performed with the *lsmeans* package.

III. RESULTS AND DISCUSSION

Regarding meat quality, only pH_{45}, T_{45}, and T_U in LTL, as well as T_{45} in SM were affected ($P < 0.05$) by the used gas for stunning (Table 1, Table 2). A significant reduction ($P < 0.001$) of LTL pH_{45} for the inert gases was found, with N_2 showing the lowest pH_{45}. These findings are in concordance to the findings of Atkinson et al. (2020) [4] and Llonch et al. (2012) [6], who also applied stunning with N_2. Additionally, Atkinson et al. (2020) [4] reported an increase of PSE meat when pigs were stunned with N_2, which was not found herein, where none of the animals showed a $pH_{45} < 5.8$. We assume that when applying inert gases, the residual O_2 content in the pit is crucial for reducing the drop in pH_{45}, which was also previously assumed by Troeger et al. (2004) [3]. Furthermore, N_2 showed significantly ($P < 0.05$) lower T_{45} in LTL and SM in comparison to the CO_2 and the Ar group, which is in contrast to the findings of Troeger et al. (2004) [3]. There, an increase of the ham core temperature was found when stunning with Ar. The T_U of LTL was significantly ($P < 0.05$) reduced in the N_2 group in comparison to the Ar group. However, it must be emphasized that despite the statistically significant differences for the mentioned meat quality

parameters, these small numerical differences have no further impact on the other tested parameters that are relevant for consumers or further processing of the meat. Out of 378 hams, 97 showed hemorrhages, most of which were recorded at N_2 stunning. However, the results show a high variability between slaughter days, indicating additional factors that make pigs susceptible to developing blood spots, such as a specific genetic background. Initial results of a genetic study carried out on this subject indicate the involvement of *EDN-1* [7].

Table 1 – Least Square Means ± SE for meat quality parameters for LTL and SM, according to the used gas for stunning. Different letters within rows of investigated muscle indicate a statistically significant difference ($P < 0.05$).

	M. longissimus thoracis et lumborum			*M. semimembranosus*		
	Ar	**CO_2**	**N_2**	**Ar**	**CO_2**	**N_2**
pH_{45}	6.53 ± 0.04[a]	6.63 ± 0.04[b]	6.50 ± 0.04[a]	6.59 ± 0.04	6.61 ± 0.04	6.58 ± 0.04
pH_u	5.50 ± 0.06	5.46 ± 0.07	5.48 ± 0.06	5.51 ± 0.06	5.48 ± 0.06	5.52 ± 0.06
EC_U (mS/cm)	4.2 ± 0.4	4.4 ± 0.4	4.2 ± 0.4	5.3 ± 0.3	5.1 ± 0.4	5.3 ± 0.3
T_{45} (°C)	36.6 ± 0.3[b]	36.7 ± 0.3[b]	36.3 ± 0.3[a]	36.9 ± 0.3[b]	37.2 ± 0.34[b]	36.6 ± 0.3[a]
T_U (°C)	6.8 ± 1.6[b]	6.9 ± 0.16[ab]	6.5 ± 1.6[a]	6.8 ± 1.6	6.9 ± 1.6	6.6 ± 1.6

Table 2 – Least Square Means ± SE for selected meat quality parameters in SM, according to the used gas for stunning, with RSF = Razor shear force, SL = Storage loss, CL = Cooking loss.

	Ar	**CO_2**	**N_2**
L(before storage)*	53.2 ± 1.1	53.9 ± 1.2	53.0 ± 1.1
a(before storage)*	8.5 ± 0.3	8.3 ± 0.4	8.4 ± 0.3
b(before storage)*	11.6 ± 0.4	12.0 ± 0.4	11.6 ± 0.4
L(after storage)*	57.4 ± 0.7	57.5 ± 0.9	57.0 ± 0.7
a(after storage)*	9.3 ± 0.5	9.3 ± 0.5	9.3 ± 0.5
b(after storage)*	13.8 ± 0.4	13.8 ± 0.4	13.7 ± 0.4
RSF(N)	12.9 ± 1.3	12.9 ± 1.3	12.7 ± 1.3
SL(%)	4.4 ± 0.3	4.4 ± 0.4	4.3 ± 0.3
CL(%)	25.9 ± 0.7	26.1 ± 0.8	25.8 ± 0.7

IV. CONCLUSION

Though the differences found here are statistically significant, they are considered to be too small to have a negative impact on consumer acceptance or further processing. When stunning with inert gases, a low residual oxygen content (< 1 %) is deemed to be of great importance for maintaining a high level of meat quality. Overall, under the conditions of this study, the investigated gas atmospheres are not inferior in terms of meat quality to stunning with 90% CO_2.

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